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NEW GLASS FOR HIGH-VOLTAGE INSULATORS

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A significant growth in the length of the high-voltage electrical network has been marked by the control figures for the development of the USSR national economy, approved by the XXIth Congress of the Communist Party of the Soviet Union. This demands considerable material resources and, in particular, a considerable number of high-voltage line insulators.

Because the demand for insulators is growing in all economic areas of the country and therefore it is difficult to count on the continual meeting of this demand by importation, the question was raised of organizing the manufacture of insulators in Byelorussian SSR. When selecting material for making insulators, it was decided to use glass since it is not only not inferior to electrical porcelain in its characteristics and properties, but in many respects is even superior. In particular, glass and glass insulators have the following advantages [1, 2, 3]:

1. Glass has greater electrical and mechanical strength than

does porcelain which makes it possible to reduce the over-all size of glass insulators as compared to porcelain ones of the same type.

2. The smaller over-all size of glass insulators makes it possible to reduce the expenditure of metal for fittings and to reduce the over-all size of LEP [power transmission line] supports or, with the same supports, to correspondingly increase the span.

3. Widely distributed and inexpensive materials serve as the raw material for the manufacture of glass insulators.

4. The technology of the manufacture of glass insulators makes it possible to completely automate the manufacturing process, hence the cost of glass insulators when mass produced would be significantly lower than the cost of similar porcelain ones.

5. The use of hardened glass supension insulators makes it possible to eliminate inspection during use by means of rods or other methods, since when the smallest defect occurs these insulators are completely destroyed (without loss of the mechanical strength of the garland), which can be easily discovered when inspecting the line.

6. Testing of finished hardened glass insulators is significantly simpler than testing of porcelain ones and can be completely mechanized.

7. The capital outlay for constructing a shop or factory for the production of glass insulators is also less than for one of the same capacity for the production of porcelain insulators.

These advantages of glass insulators were confirmed by trial use in a number of countries (England, France, Sweden, etc.), where these insulators have found wide use in electrical transmission lines up to and including 380 kv [3].

In recent years a number of studies have been completed in the Soviet Union on the questions of developing designs for glass insulators and various glass compositions for high-voltage insulators.

Considerable work has been completed in this direction by the Livov Polytechnical Institute, which recommends for this purpose regular bottle-glass with a 15-16% alkali content. As is known, alkali glass of this composition has low mechanical and thermal characteristics, however, their technological characteristics are completely adequate. In order to improve their mechanical characteristics alkali glass insulators are hardened which increases their mechanical strength 6 to 7 times [3, 4].

The All-Union Scientific Research Institute of Glass recommends glass 13-b for the manufacture of high-voltage insulators [1]. This low-alkali glass (Na_2O content of 2%) meets all of the requirements which are set forth for the manufacture of high-voltage insulators. However, technologically this glass is very labor consuming since it requires high melting and working temperatures, has a small range of working viscosity and easily crystallizes.

Investigations on the development of optimal glass compositions for high-voltage insulators are being conducted at the Byelorussian Polytechnical Institute.

On the basis of an analysis of the data from the literature and preliminary studies it was decided to search for efficient glass compositions in an SiO_2-Al_2O_3-CaO-MgO-MnO system which would satisfy the technological, physicochemical, mechanical, and electrical requirements. Such readily available materials as powdered quartz, kaolin, dolomite, limestone, and manganese ore or its by-products may be used as the raw material for this system of glass.

Table 1 shows the compositions of the experimental batches and glasses were selected for further study after preliminary experiments were conducted.

TABLE 1

Composition of Experimental Batches and Glasses

No. of Glass	Batches, parts by weight					Glass, wt. %				
	Sand	Kaolin	Chalk	Dolomite	Pyrolusite	SiO_2	Al_2O_3	CaO	MgO	MnO
19/I	31,47	12,65	10,90	45,72	11,12	55,00	5,00	20,00	10,00	10,00
19/II	31,47	12,65	1,94	45,72	16,65	55,00	5,00	15,00	10,00	15,00
19/III	43,20	25,40	14,28	22,86	16,65	55,00	10,00	15,00	5,00	15,00
19/IV	32,04	25,40	—	68,58	5,55	55,00	10,00	15,00	15,00	5,00
19/V	37,34	37,95	1,94	45,72	5,55	55,00	15,00	15,00	10,00	5,00
19/VI	37,34	37,95	14,28	22,86	11,12	55,00	15,00	15,00	5,00	10,00
19/VII	31,47	50,60	14,28	22,86	5,55	55,00	20,00	15,00	5,00	5,00
19/VIII	37,34	37,95	—	68,58	5,55	55,00	15,00	10,00	15,00	5,00
19/IX	37,34	37,95	—	45,72	11,12	55,00	15,00	11,00	11,00	10,00
19/X	37,34	37,95	9,52	22,86	16,65	55,00	15,00	10,00	5,00	15,00
19/XI	37,34	37,95	23,22	22,86	5,55	55,00	15,00	20,00	5,[illegible]	5,00
19/XII	31,47	12,65	14,28	22,86	22,24	55,00	5,00	15,00	5,00	20,00

The raw materials were pulverized, sifted, and formed into batches according to a developed recipe. The prepared batches were placed in pre-heated chamotte heating crucibles which in turn were placed in a 15-pot kerosene prototype furnace.

After trying several founding regimes the following conditions were selected as the best for ensuring complete melting, satisfactory fining, sufficient homogenization of the glass melt and a satisfactory working viscosity:

Start of charging — 1,300°C;

End of charging — 1,200°C;

Temperature rise during one hour to 1,380-1,420°C;

Soaking at this temperature for 0.5 to 1 hour;

Lowering of temperature to 1,300°C over a period of an hour;

Working at 1,300 to 1,320°C.

Thus the total melting time amounted to 2.5-3 hours.

Observation during manufacture showed that almost all glasses of this series have good working properties; they pour, extrude, roll, and are drawn into a filament well. The range of working viscosity is sufficiently large for these glasses, which facilitates the manufacture of objects of complex shapes.

In order to determine the physicochemical, mechanical, and electrical properties, samples with diameters of 150-200 mm and thicknesses of 2-3 mm were prepared with a handpress; to determine the coefficient of linear expansion, moldings and rods were stretched.

The fabricated glass samples were annealed in an electric muffle furnace according to a definite schedule and the maximum annealing temperature was 700-650°C.

In order to obtain detailed characteristics of the experimental glass, a complex method of analysis was used on which the following were investigated:

1) technological properties: melting and working capability (visually);

2) physicochemical properties: crystallization capability (polythermal method), temperature at start of softening (on the apparatus of I. I. Kitygorodskiy), density, by means of hydrostatic weighing), thermal stability (air-water method), coefficient of linear expansion (on a tube dynamometer), chemical stability with regard to water and a two-normal solution of sodium carbonate (by the powder method recommended by the VNIIS [All-Union Glass Scientific Research Institute]);

3) mechanical characteristics: microhardness and microtransparency were tested on a PMT-3 apparatus;

4) electrical characteristics were determined according to All-Union State Standard 6433-52. Measurement of resistivity was made with a galvanometer and also on an F-57 ohmmeter, dielectric loss-angle

tangent and specific inductive capacitance were measured on an MDP high-voltage bridge, and electrical strength on 60 kv, 5 kw high-voltage supply.

A comparison of the test results from numerous synthesized glasses made it possible to select the ones with the best technological, physicochemical and electrical properties (Table 2).

TABLE 2

Characteristics of Glasses Recommended for the Manufacture of High-voltage Insulators

Characteristics	Number of glass			
	19/II	19/III	19/IV	19/IX
Composition, %:				
SiO_2	55,0	55,0	55,0	55,0
Al_2O_3	5,0	10,0	15,0	15,0
CaO	15,0	15,0	15,0	10,0
MgO	10,0	5,0	5,0	10,0
MnO	15,0	15,0	10,0	10,0
Specific gravity, g/cm^3	2,91	2,73	2,71	2,72
Coefficient of linear expansion, $1/degree \cdot 10^{-7}$	52,8	51,1	45,5	52,0
Chemical stability (% loss of weight) a) water resistance	0,155	0,157	0,15	0,16
b) soda resistance	0,236	0,248	0,135	0,2
Microhardness, kg/mm^2	743	806	747	820
Microrupture strength, kg/mm^2	690	680	673	749
Thermal stability (temperature range) for sample plates 10 x 10 x 2 cm, °C	220—20	260—20	240—20	260—20
Volume resistivity at 20 °C, ohm • cm	$9 \cdot 10^{15}$	$4 \cdot 10^{13}$	$3 \cdot 10^{15}$	$1,5 \cdot 10^{15}$
Surface resistivity, ohm: a) at 65% humidity	$7,5 \cdot 10^{11}$	$1,2 \cdot 10^{13}$	$1,5 \cdot 10^{11}$	$1,1 \cdot 10^{15}$
b) at 95% humidity	$3 \cdot 10^{11}$	$8,2 \cdot 10^{11}$	$1,6 \cdot 10^{10}$	$7 \cdot 10^{11}$
Specific inductive capacitance	7,73	11.9	7,55	8,3
Dielectric loss-angle tangent at 20°C	0,0026	0,0468	0,0029	0,012
Electrical strength, kv/mm	>30	>30	>30	>30

The technological characteristics of these glasses are as follows:
Melting temperature (in a laboratory kiln) — 1,380-1,420°C;
Working temperature — 1,300-1,320°C;
Maximum annealing temperature — 650-700°C;

Temperature at start of softening — 745-780°C.

Glasses 19/II and 19/III have the greatest crystallization capability while glasses 19/IV and 19/IX crystallize just like normal industrial glass.

CONCLUSIONS

1. As a result of the work carried out, glasses were obtained that were suitable with respect to a complex of properties for the manufacture of high-voltage insulators. Abundant and inexpensive materials serve as the raw material for these glasses.

2. The final refinement of all characteristics and final working out of recommendable compositions of the glasses must be carried out during the manufacturing of test batches of high-voltage insulators under industrial conditions on machinery of factory size.

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